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We are met here today to consider some of the frontier scientific and technical problems of the rapidly advancing technology of aeronautics. The scientists and engineers among us are interested in these problems because of their technical challenge, our desire to understand their essential features, and our urge to participate in the accomplishment of new goals. The industrial members of the team are interested in increasing the stockpile of information, in enlarging the variety of principles and methods from which a harmonious and useful device may be created and built. The military members of the team are searching for quantum jumps in weapon design, pressuring the others to move faster, and to make good their promises of accomplishment. For all of us, with an eye on a strong competitor, the advancement of aeronautical technology is serious business, vital to the continuing security of our nation and other nations who prize the freedom of individual citizens.

We scientists think of our work as the foundation on which technology is based. We boast of whole new industries based on the discoveries of scientists unknown to previous generations, electronics, nuclear technology, and so on. Yet it takes more than scientific discovery to

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make a new technology or advance an old one. Discovery is essential but not sufficient. Prandtl boundary layer theory lay dormant for 25 years, and his graduate students who chose this field for a thesis had to abandon fluid mechanics for some other field in order to make a living. Supersonic theory was largely a mathematical exercise through most of the first half-century of flight. And I fear that much of the work of astromantis,^m photon rockets and similar devices is a bit ahead of its time. Let us emphasize the necessity of free exploratory basic research and its prospective great return to the society which supports it but let us not minimize the great effort needed to erect the superstructure of technology on which practical development must be founded.

There is an interplay between science, technology, and practical development, each dependent on the other. A fine sense of timing is needed if progress is to be most rapid yet soundly based. The procedure is somewhat as follows. From the sum total of knowledge and experience available to him, some creative intellect envisions a new device. Often in the face of considerable criticism he makes the device and immediately begins to learn something of the patterns which he did not foresee. If the device

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proves useful, the scientists and engineers are stimulated to conduct basic and applied research to improve the device. In many cases the build-up of interest and effort is slow; in others the time constant is shorter as in radar, nuclear devices, and supersonic military aircraft. It is essential that this time constant be as short as possible in the development of military weapons.

It is apparently my function as Keynote speaker to present to a certain degree the direction in which practical developments are moving and the research foundations which should be laid to support these developments. But first I wish to make an affirmation of faith with which you may or may not agree. It is to the effect that man is and always will be a vital element in every weapons system and in particular that there will always be a need for the human fighter in the vehicle whatever its ultimate performance. In other words guided missiles will supplement but not replace piloted aircraft. Though we may do our first space travel with an unmanned satellite, I am confident that ultimately one or more men will be on board.

Although the human pilot has many limitations, necessitating the provision of a special environment, and many

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desire to assist his senses, he has qualities of judgment and flexibility of reaction to unforeseen phenomena not to be found in any artifact man has yet devised. Actually electronic and other equipment requires the same special environment; in the X-15 research airplane the demands of the pilot for reproduction and ventilation are small compared to that of the instruments and control equipment. Further the costs of the new weapons, ^{comes} are becoming so great that we need the man to bring the carrier back for reuse. This belief in the future of hypersonic manned aircraft acts in no way to limit the performance of future weapons systems with the possible exception of maximum acceleration, though here again both electronic devices and structure are also acceleration limited.

The three basic performance parameters of aerautical devices are speed, altitude, and range. The user would like all three to be as large as possible, but Nature is not so kind. The requirements for maximum speed, maximum altitude, and maximum range lead to conflicting demands on the designer. In general the designer has in mind at two general classes of vehicles with many subtypes. In the fighter, speed and altitude are maximized and in the bomber or transport range is

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given predominance. These statements are over simplifications. In a recent discussion of nuclear powered airplanes, the claim was made that the ~~independent~~^{very long} range was of great military value. This is true but other aspects can not be neglected. I pointed out that the rigid airships also had a very long range but had not proved to be a very useful military vehicle.

Let us however discuss the outlook on the speed and altitude frontiers. Many of you have seen various representations of where we are and the new vistas opened before us by the new developments in aerodynamics, powerplants and structures. In the first 44 years of flight, ^{piloted} airframe speeds increased at the rate of about 15 miles per hour per year. Then in the six years and two months between passing Mach number 1 on Oct 14, 1947 and $2\frac{1}{2}$ on Dec 12, 1953 the rate was 160 miles per hour per year. We have since passed 3 and confidently look forward to 7 with U-X-15. With unmanned vehicles we passed 10 not too long ago and expect 20 within the next few years. Attainment of escape velocities will not be long postponed. Perhaps we will not make all our predicted steps exactly on schedule; but the way is clear of any known insuperable obstacle and only the timing is uncertain.

Similarly on the altitude frontier. We have already surpassed 100,000 feet with piloted aircraft and

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will often reach twice this value with the X-15. The first satellite will reach 200 to 300 miles in a few years.

When we examine the types of vehicles in more detail we find that technology limits us to certain regions of a speed-altitude chart for sustained flight. In very general terms if we attempt to go too fast at the lower altitudes, aerodynamic heating produces temperatures beyond the capabilities of known materials and structures. If we do not go fast enough at the higher altitudes, we can not develop sufficient lift. Increasing wing area defeats itself through added weight and drag. According to most computations there is a narrow corridor of ~~wide~~ speed and altitude in which sustained flight is possible. It corresponds to a Mach number of 7 at an altitude of 25 miles, both altitude and speed increasing to Mach number of 25 at an altitude of 50 miles. Some estimates fix the corridor as about 5 miles wide in the altitude coordinate. These computations together with other experimental data suggest the ultimate development of a hypersonic winged glider boosted to high speed and altitude by a rocket motor.

The ultimate in high speed flight if we may call it flight is the satellite vehicle. If the speed is ade-

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correctly to the altitude, we may regard it as a vehicle supported at constant altitude above the earth by centripetal force or instead from space as a vehicle falling at just the rate to follow the curvature of the earth.

As many of you know, there is under design and construction for the Air Force, Navy, ^{and} ~~NASA~~ the X-15 research airplane designed to study the expected problems of the speed and altitude portions and perhaps to reveal unexpected problems. The skin will be made of material permitting surface temperature of 1200°F , thus permitting study of the effect of the heat on the aerodynamics and on the structural behavior. It will be possible to project the X-15 to attitudes where steady flight is not possible, to study attitude controls based on rockets, and to accomplish safe reentry. Reentry periods of flight on a ballistic trajectory will be possible.

It is possible to convert the speed-altitude plot to a form more suggestive of ^{some of} the aerodynamic problems. The aerodynamicist makes use of the Reynolds number, Mach number and Knudsen number as parameters to define types of flows.

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The most severe aerodynamic heat problem is that of the reentry of the nose of a ballistic missile. Here the maneuver is essentially fixed, although purposeful variation of the drag-weight ratio materially affects the heating. As is well known, development of the IRBM and ICBM's are proceeding with high priority.

The speed and altitude frontiers are thus being explored by practical devices and the design and construction of these devices highlight many problems of basic and applied research. The heat transfer depends very much on whether the flow is laminar or turbulent. The design needs firm attention on our ignorance of the fundamentals of transition and on the practically attainable values at high supersonic speed, on the effects of shape, of surface roughness. We find that our knowledge of the practical boundary between slip and continuum flow is insufficient. ^{We have investigated briefly the aerodynamic effects associated with high supersonic speeds and typical heat transfer. Effects is they time at high supersonic temperatures stability patterns have been revealed both} Our knowledge of the behavior of materials in the high speed, thermal, and chemical environment of hypersonic flight is primitive. Many of the problems are not amenable as yet to theoretical treatment. Much ingenious effort is needed to devise methods of

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environmental testing with practically ground equipment. The program of the conference contains papers on many of these topics.

I will not discuss the range frontier at length since the conference does not consider the subject of propagation. The aerodynamicist should remember that lift/drag ratio is a direct factor in range and that any improvement is reflected as a corresponding improvement in range.

In closing, I wish to emphasize the great responsibility which we share together. I detect in some of the ^{topics} headings of the program an ~~over~~ emphasis which I have also felt recently in our NASA contacts with industry and the military, ~~in emphasis on~~ rapid completion of the step from idea to ~~a weapon~~ ~~and~~ adequately supporting the new technology by applied research on suggestion of the user's need for devices ~~available for~~ ~~adapted to~~ the environment of their use, fully tested and reliable. ~~Let us make our case for the extension of basic knowledge, but let~~ This is an emphasis which ^{on a different basis of engineers} in addition to continue advancing the frontiers of research, research and development people need from time to time. The keynote is therefore a chord rather than a single note just as our task is a team task. Let's get on with the job.

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